

Germanium Blocked Impurity Band Detectors

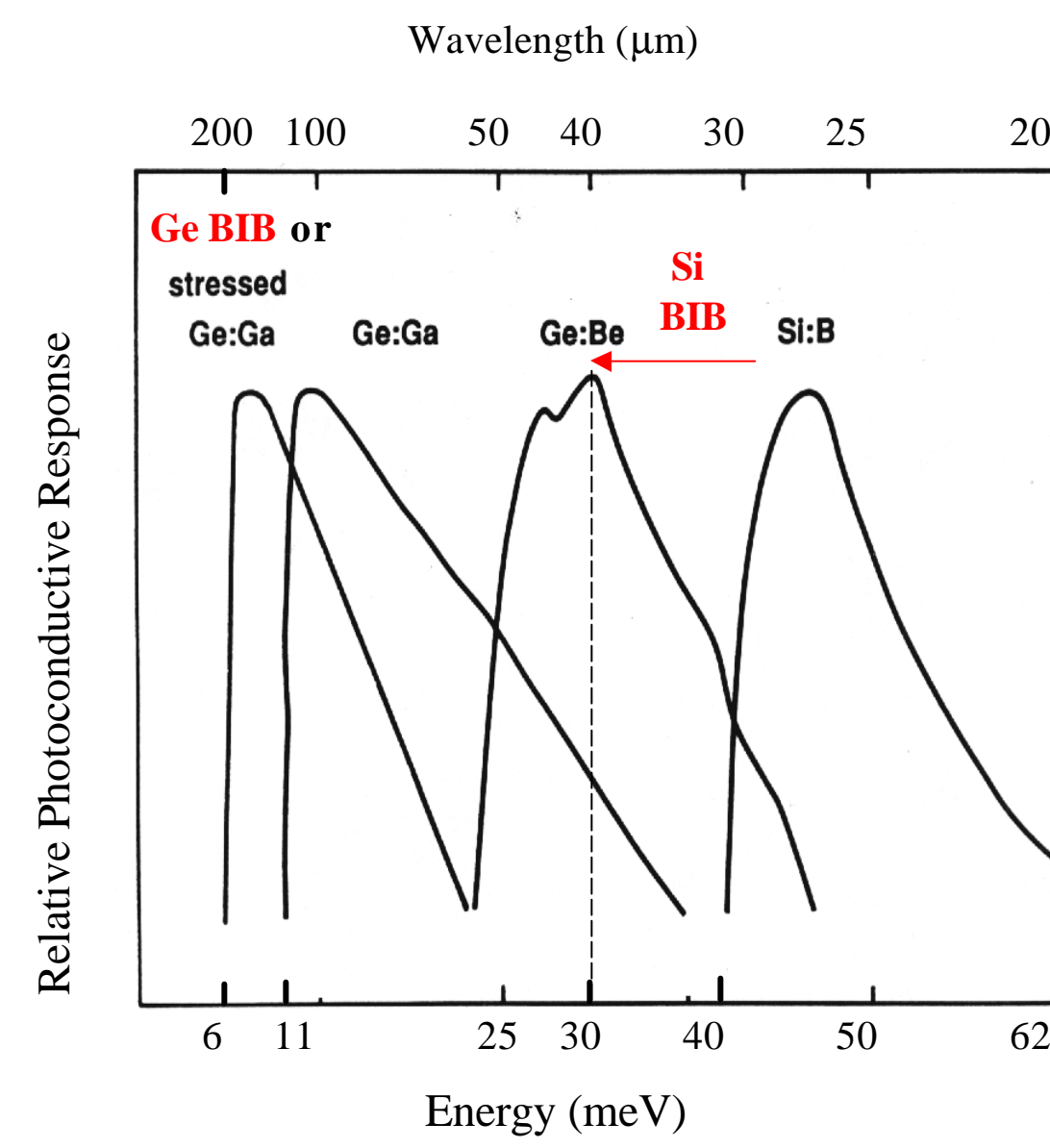


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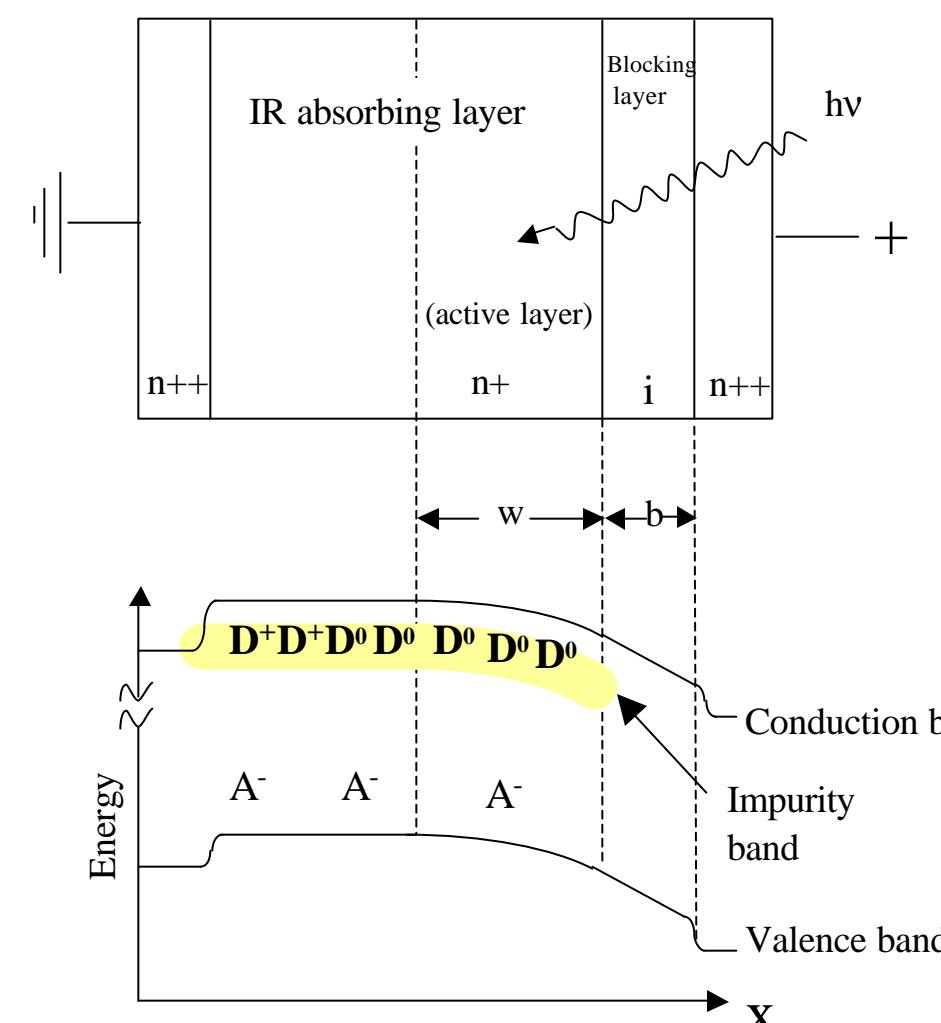
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Current Far Infrared Photodetectors



BIB Detector Operation



- Photon absorption in n+ region
- Newly generated free carriers drift through the blocking layer into the contact
- D⁺ move toward the negative contact
- Electrons in the donor band cannot pass through the blocking layer since no impurity band exists there

Ge BIB Requirements

- Blocking Layer
 - Thin blocking layer (1-10 μm)
 - High Purity ($N_D < 10^{13}/\text{cm}^3$)
- IR Absorbing Layer
 - Dopant with low ionization energy for long wavelength detection e.g. Sb ($N_D \sim 10^{16}/\text{cm}^3$)
 - Only carriers generated within the depletion layer drift into the blocking layer. To obtain a thick depletion layer, it is necessary to have $N_A \sim 10^{12}/\text{cm}^3$. Depletion region thickness is given by:

$$w = \left[\sqrt{\frac{2\epsilon\epsilon_0(V_a - V_{bi})}{eN_a}} + b^2 \right] - b$$
 (b is blocking layer thickness)

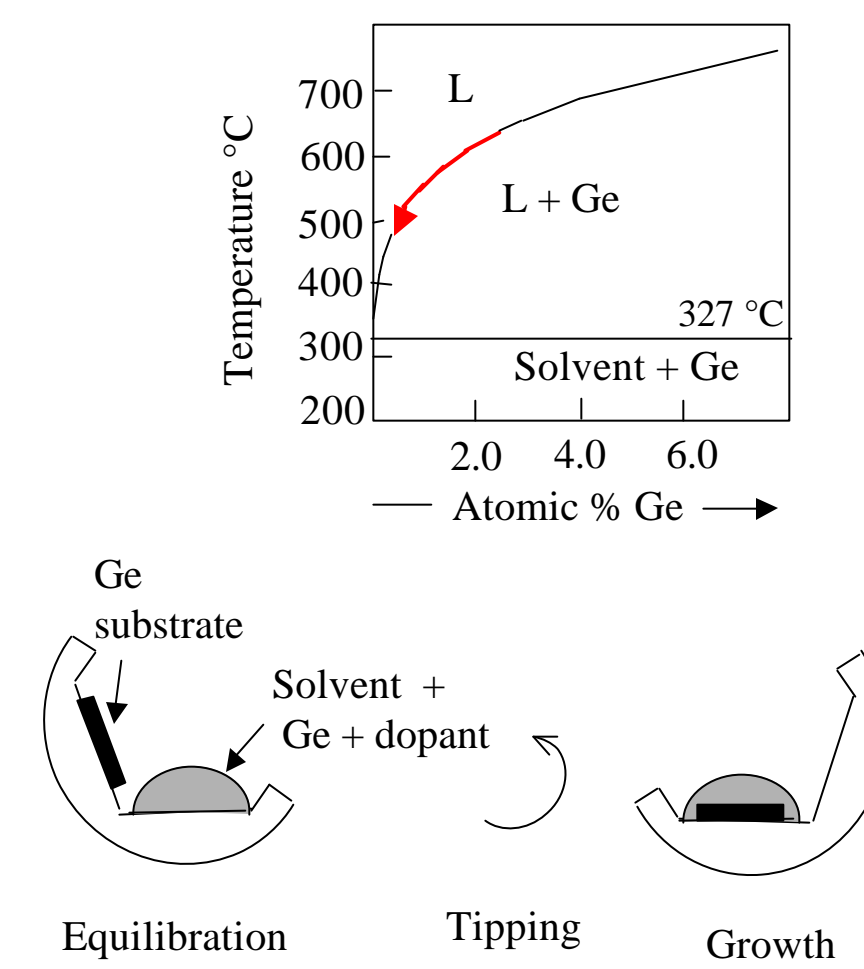
Predicted BIB absorption versus minority doping concentration

$N_d = 1 \times 10^{16} \text{ cm}^{-3}$, $\alpha = 100^\circ \text{ cm}^{-1}$, $\lambda = 200 \text{ μm}$, $b = 10 \text{ μm}$

N_a (cm^{-3})	Bias (V)	w (mm)	Percent Absorption
1×10^{13}	1.5	9.12	15
5×10^{12}	1.5	15.12	21
1×10^{12}	1.5	42.49	40
7×10^{11}	1.5	52.39	46
5×10^{11}	1.5	63.55	52

* From reference 1

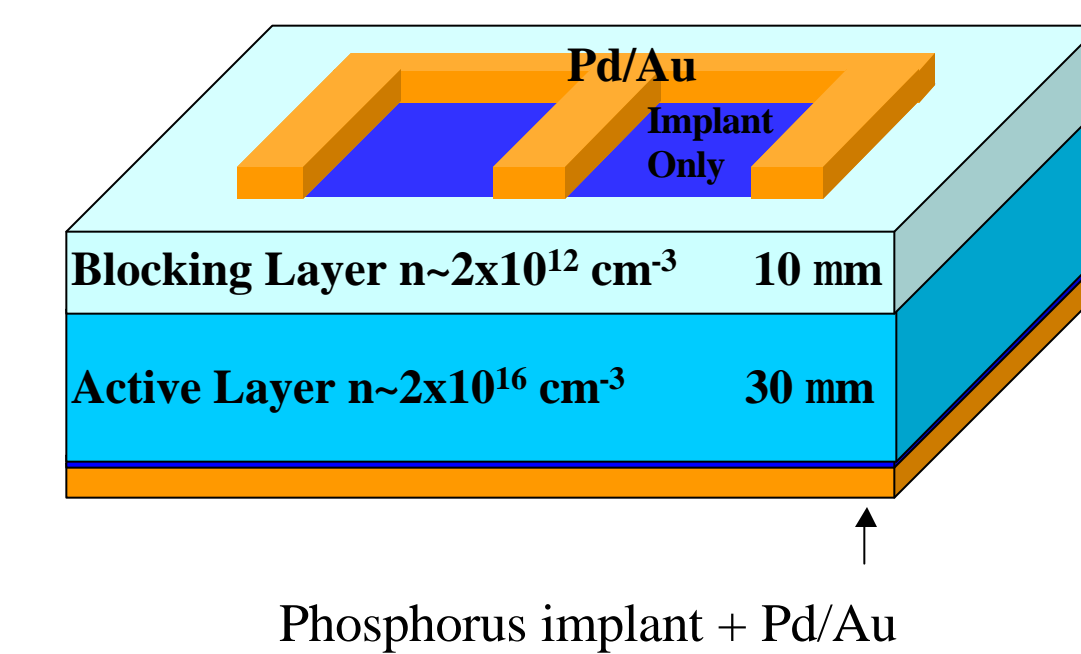
Liquid Phase Epitaxy



- Graphite crucible heated in H₂ atmosphere
- Ge (and Sb) dissolved in Pb solvent at elevated T
- Melt poured onto Ge substrate
- Solution cooled
- Ge (and Sb) epitaxially grows onto Ge substrate as temperature is lowered

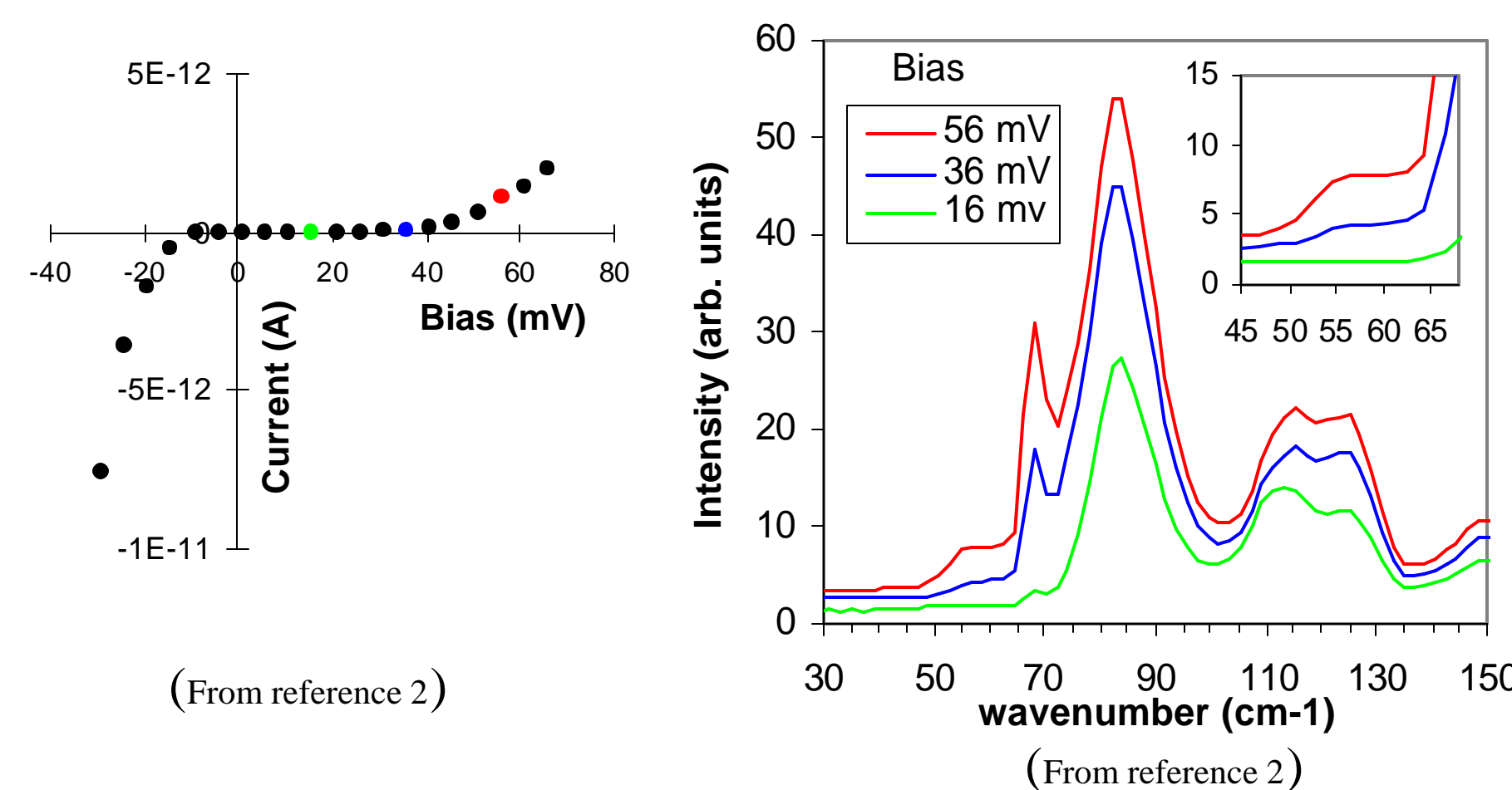
LPE can give very pure films due to segregation of impurities to the liquid phase

BIB Detector Fabrication



BIB detectors have been fabricated by growing Sb doped Ge layers epitaxially on pure Ge substrates, and then polishing back the substrate (to ~ 10 μm) to form the blocking layer. The IR active and blocking layers are P implanted to form back and top contacts. The contacts are metallized with Pd/Au. The top contact is 50% transparent to IR radiation.

BIB I-V and Spectral Response



Long wavelength response is observed compared to a standard Ge:Sb photoconductor

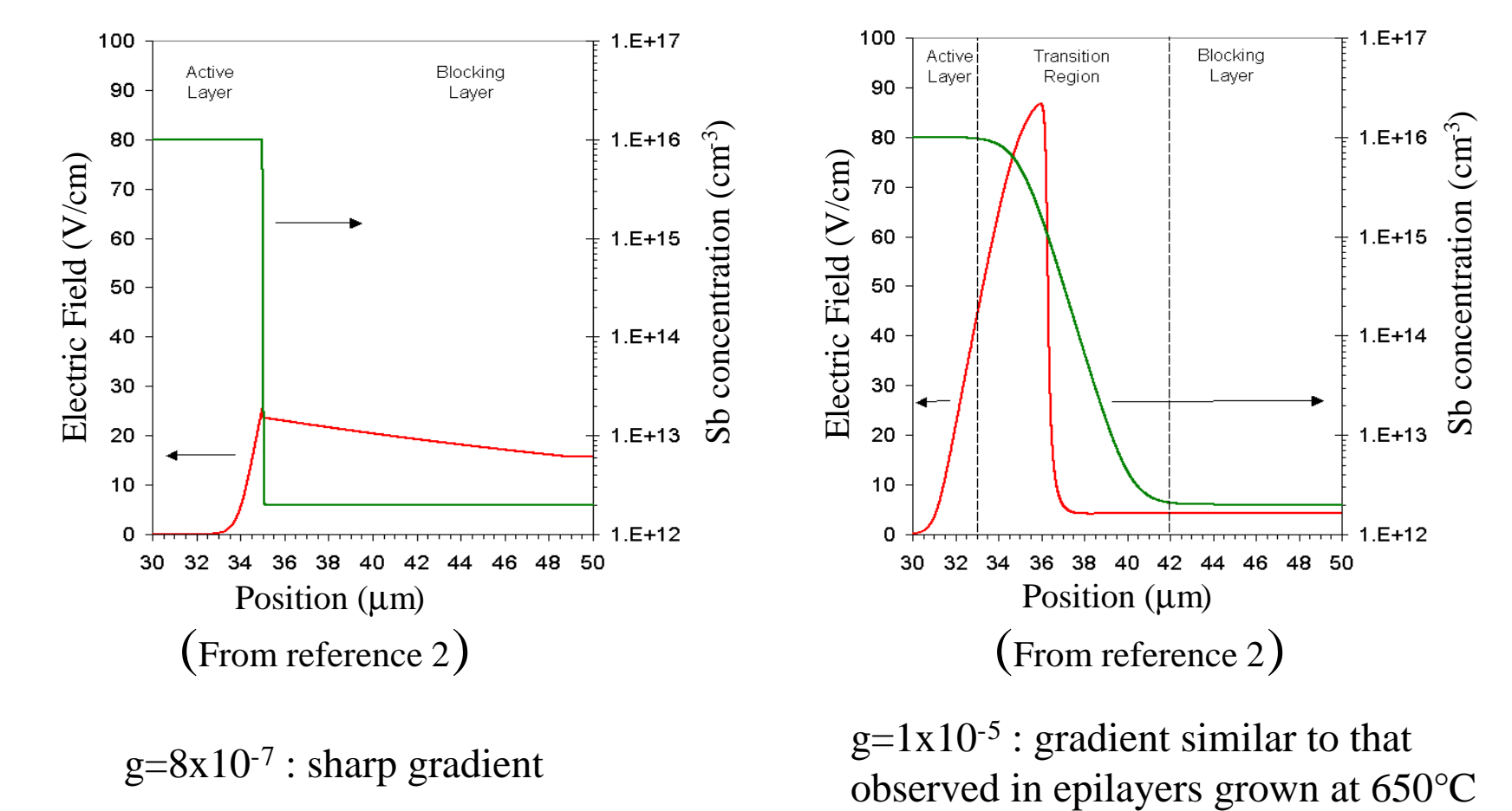
Sb Diffusion into Blocking Layer

- Distribution of Sb in doped Ge layers has to be determined accurately due to its potential effect on electric field distribution in BIB devices
- SIMS data shows significant Sb diffusion into the blocking layer for layers grown at 650°C. Sb concentration drops an order of magnitude over 1.5 microns
- A BIB model has been developed in order to understand the effects of BIB parameters on electric field distribution in a device
- Gradients in Sb concentration (N) across the interface have been considered, and are defined by a grade parameter g

$$N = N_1 + \frac{(N_2 - N_1)}{1 + \exp[(a - x)/g]}$$

N_1 , N_2 are layer dopings, a is the interface position, and x is the position variable

BIB Detector Modeling



- In the blocking layer, field is low- could affect gain in the device
- The depletion width of the device (if ~ 1 μm) would have lower Sb concentration, reduced long wavelength response expected
- Extreme diffusion of Sb into blocking layer would reduce its blocking effectiveness

Future Work

Sb Diffusion

- Sb-doped layers grown at lower temperature (550°C) show a sharp interface with no observable diffusion. However, these layers are only 10 μm thick
- There is a need to grow thicker films at lower temperatures

Pb Purification

- The purity of commercially available Pb has been found to be a problem, with n-type impurities ~ 10^{15} cm^{-3} , identified by photothermal ionization spectroscopy to be phosphorus
- Purification of Pb using Zone Refining would enable growth of both pure and doped layers for BIB detector fabrication

References

- + Current address: Jet Propulsion Laboratory, Pasadena, CA, 91109
- 1. J. Bandaru, J.W. Beeman, E.E. Haller, accepted for publication in Applied Physics Letters
- 2. J. Bandaru, J.W. Beeman, E.E. Haller, Stacy Samperi, Nancy M. Haegel, accepted for publication in. IR Physics and Technology

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